The geography of innovation : challenge to technology policy within regions

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THE GEOGRAPHY OF INNOVATION :
CHALLENGES TO TECHNOLOGY POLICY WITHIN REGIONS

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"The economic future of the Regions is conditioned by their capacity to create knowledge, to access knowledge, to use knowledge." (P. Maskell, 2001)

The "Geography of Innovation"[1] is based on the desire to give empirical foundations to the explanations behind the pronounced spatial polarisation of the innovation activities. It focuses on an attempt to measure the spatial dimension of knowledge externalities, in order to reveal their role in the organisation of research systems.

The aim of this paper is to survey this empirical literature in order to highlight the main results interesting for the innovation policy. This analysis emphasises one main role of technology policy : supporting the institutions which generate knowledge and learning. These are found at various territorial levels, especially within the European Union. Here attention is drawn to the regional intervention level.

Keywords : technology policy, geography of innovation, knowledge externalities, European regions, knowledge-based economy.

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[1]Term taken from Feldman's work (Geography of Innovation) published in 1994, which stands as one of the main references in this field.

1. INTRODUCTION

During the last decade, numerous studies have highlighted the pronounced spatial polarisation of innovation activities, in the United States and within the European Union [2]. From the empirical studies we know that there are many determinants for the localisation of innovation. For a large part, they correspond to the existing location of production activities, but they also follow the geographic distribution of demand, specialised service activities, and depend on the availability of a qualified labour force in large urban agglomerations. But this hardly explains the characteristics of the location of innovative activities which systematically seem more concentrated than production activities.

In the main, the theoretical models rely on the assumption of a geographic dimension of knowledge externalities in order to justify such specificity and the resulting dynamics of differentiated growth. One main result of the Economics of Innovation is indeed that the technological knowledge is not only an output of the R&D activity, but that it is also its principal input. This result justifies the focus on technological spillovers and the deriving assumption that the knowledge externalities can be geographically bounded. But until the early 1990's this assumption had virtually no empirical support.

The "Geography of Innovation"[3] is based on the desire to give empirical foundations to this explanation behind the pronounced spatial polarisation of innovation activities. It focuses on an attempt to measure the spatial dimension of knowledge externalities, in order to reveal their role in the organisation of research systems within each nation, and the relative weight of the local determinants in such an organisation. This is why this econometric literature is interesting for the regional science and technology policies. It confirms some current orientations. The methods of applied economics used in the Geography of Innovation[4] provide empirical results which allow some comparisons between various institutional contexts. Furthermore, the preferred observation levels are government-defined areas, in other words : areas which are pertinent in terms of public policies[5].

This article surveys the results obtained in the United States and the recent analyses within the European Union. It emphasises one main role of the technology policy : supporting the institutions which generate knowledge and learning.

The diffusion of technological knowledge (the degree and channel) depends indeed on the institutional structure. Here attention is drawn more specifically to the regional intervention level.

At the present time it is widely accepted that public policies conceived to form a Silicon Valley type technology area are utopian (M. Maggioni, 2001). However, regional policies have a role to play in technology, as confirmed by the Geography of Innovation.

[2] D. Puga (1998), M. Amiti (1998), OST (1998) and R. Paci and S. Usai (1999) notably.
[3] Term taken from Feldman's work (Geography of innovation) published in 1994, which stands as one of the main reference in this field.
[4] See C. Autant-Bernard and N. Massard (1999) for a critique of these methods.

By taking the analysis of technology externalities further, by better describing the sources, paths and methods of transmission, this empirical literature helps to specify the conditions whereby the effects of proximity may act positively, which justify regional policies for economic development (§ 2 and § 3). Nevertheless, it also clearly shows that even where they exist, the effects of proximity are never exclusive, and interact with effects far more remote nationally and internationally, which trigger even more reasons for regional public interventions (§ 4).

[5] States or metropolitan areas in the United States, regions or departments in France.

2. THE SCIENCE-INDUSTRY RELATIONSHIP AND THE NATURE OF KNOWLEDGE

Analysing the effects of proximity in research and development (R&D) and local innovation reveals the source of the geographical spillovers. Many works advance the role of public research in the production of knowledge externalities. The relationship between public research and private business is regularly studied as the relationship between Universities and Industry, because in most advanced countries Universities are one main generators of new knowledge and the key components in the public research system.

2.1. The geographic dimension of public externalities

2.1.1. The role of the institutional context

Deriving from A. Jaffe's work (1989), early studies conducted into the Geography of Innovation focussed mainly on the United States and were based on data from the 80's. Here, all the studies concluded with the localised aspect of technological externalities or, on a wider level, with the marked sensitivity to geographic proximity of the science-industry relationship within the States and the Metropolitan areas.[6]

Extending this empirical concern to more recent periods and other countries[7] has greatly contributed to qualifying this initial result. Certain analyses broaden markedly what is taken as "local". For instance L. Bottazzi and G. Peri (2001) work within a radius of 300km. Others question more directly the hypothesis of the impact of geographical distance on the science-industry relationship (M. Beise and H. Stahl – 1999). As for France, it would certainly seem that the system of innovation, famed for according considerable weight to public research, reveals some specificities in relation to the American case (C. Autant-Bernard, 2000b). Globally, C. Autant-Bernard shows that technological externalities from public research are definitely present within innovation and private research. However, the local dimension to these externalities is not very pronounced. Overflow effects occur at a greater distance. So we do not find the same results than the studies carried out on American data indicating a geographic dimension supported by the overflow effects from public research.

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[6]E. Mansfield (1995a); E. Mansfield and J. Lee (1996); Z. Acs, D. Audretsch and M. Feldman (1991); M. Feldman (1994); L. Zucker, M. Darby and J. Armstrong (1998); Z. Acs, L. Anselin and A. Varga (1997) notably.

[7] in particular C. Antonelli (1994), R. Paci and S. Usai (2000), L. Bottazzi and G. Peri (2001) for Italy; M. Kenney and R. Florida (1994) for Japan; K. Blind and H. Grupp (1999), M. Beise and H. Stahl (1999) for Germany, C. Autant-Bernard (2000) for France.

Among the explanations for this difference in results, the institutional factor certainly plays a determining role. Despite a noticeable evolution in recent years[8], the French institutional context is quite different to the American case because of the less pronounced links between Universities and Industry, and a predominant Paris-provinces structure. Perhaps as an initial conclusion it could be said that American public research is more "applied" than French public research – which would explain the stronger influence of geographic proximity on the spillover from this research. We may then defer making the distinction regarding the level of fundamental or applied knowledge in order to differentiate the effect of geographic proximity.

2.1.2. The nature of the knowledge transmitted

In order to differentiate academic and applied research without invoking the public/private distinction, the chosen method involves using the temporal dimension of these innovation processes. This is the study of observable differences between what happens in the phases upstream of the innovation processes (the research phase) and what happens in the more downstream phases (innovation, filing a patent). M. Feldman (1994) here notes that research activities are more influenced by the close presence of a university than the actual innovation phase. In the American context, the primordial role of proximity would thus be particularly noticeable in the initial stages of research. Similarly, in the French case, the geographic dimension of technology spillover varies according to how their effect on R&D or patents is considered. C. Autant-Bernard (2000) shows that while the ratchet effect of public research on private research activities undeniably includes a local dimension, the repercussions of public research on the production of innovation itself are far more diffuse in the geographic dimension.

She considers that this confirms the idea of a stronger localisation at a time when knowledge, still poorly codified, necessitates a physical proximity between individuals in order to be transmitted. Conversely, when defined in the form of a patent, it becomes less tacit and can be transmitted across a distance [9].

Nevertheless, this result poses a few problems of interpretation in so far as it supposes that tacit knowledge is more characteristic of upstream research phases, while the application of innovations would bring codified knowledge into play. After the fashion of E. Mansfield (1995a), it is therefore customary to assimilate tacit knowledge at the industrial research stage, with academic research tending more to widely diffusible codified knowledge. Generally speaking, empirical results show that no simple relationship can be established on this point, as all research and innovation activities often

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[8] For a description of recent institutional evolutions in the French innovation system, see Mustar and Laredo. (2001) as well as M. Bellet , N. Massard, and P. Solal (2002).

[9] C. Autant-Bernard (2000) shows that the influence of time on the geographic dimension of the externalities of knowledge has also been particularly studied within works on patent citation in the United States. Hence, A.

combine both forms of knowledge. Overall, such a dichotomous representation which juxtaposes, on the one hand, public research/academic research/codified knowledge/low influence of geographic proximity and on the other hand, private research/industrial research/tacit knowledge/strong influence of proximity, is largely discredited by empirical studies. Whether the research is academic or industrial, today it can originate as much from public as private research and must, in order to be transmitted, associate a transfer of codified knowledge and tacit knowledge.

The features of the "French model" of public-private relationships have a positive aspect: the transfer of knowledge between academic research and industry happens less via direct - hence specific and localised - relationships than via a widespread diffusion of scientific achievements, likely to benefit the system as a whole.

However, this institutional organisation has its limits. Codified knowledge (the characteristic needed for a widespread diffusion) is generally insufficient for the commercial exploitation of a scientific achievement. Part of the new knowledge remains tacit, ie embodied in the researchers. The commercial application of a scientific achievement also implies that industrial firms have access to this knowledge. The importance of direct relationships, otherwise known as active connections, is emphasised by the results of the Geography of Innovation.

2.1.3. The importance of active connections

In their study of biotechnologies in the United States, I. Cockburn and R. Henderson (1998) using data of joint publications advance the role of direct collaboration between private and public sector researchers in harnessing public externalities. Their approach contains no geographic dimension, however. Even scarcer, the few works which deal simultaneously with direct relationships between researchers and the local dimension of knowledge flows may be grouped into three categories. Using joint publication data as an indicator of effective scientific collaboration, an early type of method tries to map the coincidences between the structure of scientific relationships and the geographic structure (see M. Katz, 1994 on joint publications and more generally the bibliometric literature on establishing cartographies for scientific relationships). With their more interpretative content, the second type of works tries to tie the innovation output to the scientific connections established at different geographic levels. In this field L.G. Zucker, M.R. Darby and J. Armstrong (1998) show the importance of local relationships between companies and university researchers in harnessing externalities; P. Almeida and B. Kogut (1999) for whom the professional mobility of inventors is an important factor in the location of patent citations or C. Autant-Bernard and N. Massard (2000) on the impact of joint publications between French departments in the transmission of knowledge externalities. Lastly, the third type of analysis relies on the same data but reverses the

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Jaffe, M. Trajtenberg, and R. Henderson (1992 and 1993) as well as B. Maurseth and B. Verspagen (1999) in the European case, note a decline in the localisation of patent citations in the course of time.

problematic by using econometric methods to assess the determinants for the observed scientific relationships and more particularly to define the importance of the explanations based on the geographic proximity (B. Maurseth and B. Verspagen, 1999).

All in all, these studies analyse the links between the geographic dimension, interpersonal interactions and externalities of knowledge. The following is the tested hypothesis: externalities are mediatised by the interactions between individuals, and these interactions are in turn facilitated by geographic proximity. Hence, this rather marked incidence of interpersonal relationships on knowledge flows is undoubtedly one of the main reasons for proximity effects. As people's mobility is circumscribed geographically and the likelihood of encounters is facilitated by proximity, publication is particularly fostered within built-up areas. However, empirical works in this field are still rare. They come up against the difficulty of finding data which are representative of the diversity of formal and informal interactions which could lead to knowledge publication.

This accent placed on interpersonal relationships, in association with the notion that these relationships would be facilitated by geographic proximity, is a notion which has often been challenged since the mid 90's. Particularly at issue is the impact of the ITC on the geographic structuring of scientific and technological exchanges. Initial studies carried out in this field show that there is no doubt that the intensity of interactions and especially remote interactions and the associated knowledge flows has massively increased, but the spatial distribution has not fundamentally changed. Hence for E.L. Glaeser (1998) who questions the future of towns, electronic contact and face-to-face relationships together respond to a growing need for interaction and information and through their complementarity strengthen the pull of built-up areas. But here again, empirical studies are sorely lacking. They struggle to find pertinent data enabling a true estimation of the effects of ITC on the geographic dimension of knowledge externalities.

2.2. Relying on the presence of a University

2.2.1 Ensuring the compatibility of two logics

The results of the Geography of Innovation show that, within some institutional contexts - like with the French case - the improving of the links between science and industry at the regional level is a justification for a public intervention.

Despite its strategic importance in a "science-based economy", where the links between science and technology are particularly close, this connection risks being inadequate because it is not natural. Universities, which occupy a central place in the generation of knowledge, and industry correspond to two different worlds with specific codes, cultures, reward systems and final objectives. Such a characteristic involves bridging problems between these two spheres.

A second fundamental reason legitimising a public intervention in this field is the need to monitor the conditions of the science and industry getting together. This in effect brings with it the danger of nullifying the advantages of the "open science" (P. Dasgupta and P. David, 1994[10]). The scientific community has traditionally played a key role, not only in the creation of knowledge but also in its widespread diffusion. In this system, the "knowledge dilemma[11]" is resolved by a means of remuneration specific to the university (reputation in the scientific community through publications) which ensures an effective compromise by simultaneously stimulating research and knowledge communication initiatives.

Now, the knowledge dilemma is heightened as soon as there is a tying link between the scientific and industrial domains (P.B. Joly, 1992). Academic research, which generates strong knowledge externalities, was traditionally in the public domain. For this reason the nature of the technological knowledge as public property (K. Arrow, 1962) did not pose a problem. Alongside this, the patent was exclusively used by industry. This incentive system founded on exclusion[12] has shown itself to be adequate bearing in mind the fact that the externalities of the applied research are weak.

At the present time we are witnessing on the one side a growing tendency to protect the knowledge resulting from public research (connected to a new concern to valorise the results of this research), and on the other side the development of externalities resulting from private research (connected with the rise in private funding of R&D activities and the growing involvement of large industrial groups in basic research). This is why the universities are decreasingly the only players in the generation of new knowledge but are more often the heart, the central point of the networks of public actors / private participants in knowledge generation and diffusion. D. Foray and J. Mairesse (2001) argue that such a specificity constitutes the very definition of a knowledge-based economy: an economy in which knowledge externalities are more powerful than before. This does not change the nature of the knowledge dilemma, but its degree. This is why "*the institutional compatibility of open knowledge with private incentive structures is one of the most important compatibilities for the future of knowledge-based economies*." (D. Foray and J. Mairesse, 2001).

Accentuating the interaction between the two spheres of knowledge represented by universities and industry seems now vital. Universities are pushed towards opening up to external players (particularly companies), finding the ways in which their research results can be valorised in order to contribute to the regional economic development. However, in order to perpetuate the interest of the interaction between science and industry, each sphere must retain its own specificities. Among other things, this would signify that the university should not become a service provider at industry's beck and call.

[10] Pionneer's work on the opposition between « private technology » and « open science ».
[11] The dilemma between the logic of opening-up - that is to say the widespread diffusion of knowledge which increases its social value - and the logic of clamping down (such as intellectual property rights) necessary to stimulate research (P.B. Joly, 1992 or M. Fadairo, 2001 for example).
[12] As it establishes a monopoly of exploitation.

2.2.2. *Promoting science-industry transfers and cooperations*

The objective is to enhance the transformation of scientific results into competitive performances, in other words, to improve the diffusion of the academic knowledge throughout the local industrial structures, whilst ensuring that the "open science convention" (Foray, 1997) is not fundamentally challenged.

In spite of the main differences outlined above, between the scientific and the industrial fields, the interaction of these two areas is possible because of the existence of common or complementary objectives on which public intervention can be based. Hence the accumulation of knowledge is an objective common to both the industrial and the scientific fields. Moreover there is an emerging complementarity between the search for technological advance of industry and the search of financial resources at the scientific level.

From a general point of view, what is at stake for the public authorities is the implementing of "distribution-orientated institutions" which favour the diffusion of technological knowledge (P. David and D. Foray, 1994) whilst being sure that the level of research incentive is sufficiently high.

The science-industry relationship can take diverse and complementary forms according to the extent of its embodiment (M. Gittelman, 2001) : it can be anything from simple transfer to complete cooperation between the two spheres.

Apart from publications, specific to the "open science", patent is the most disembodied transfer media between science and industry, because of its informational content (M. Fadairo, 2001). For this reason this institutional mechanism is at its most effective when it is operated at the highest territorial level (EU based within the European Union). However, the regional authorities have a role to play here : facilitating access by local companies to the information contained in the patents (information, advice, tax incentives for licence purchasing …).

Nevertheless, the interaction of science and industry at regional level, in other words within a given institutional and territorial framework, more often takes a more embodied form, formal or informal. Hence a number of studies looking into the local character of relationships between universities and industry underline the importance of informal links like seminars, consultations or visits to laboratories. These informal links are a good way for opportunities. Formal relationships between science and industry take the form of contractual arrangements with varying durations: funding granted by private companies, research shared between public and industrial laboratories, "hiring" students. The highest degree of transfer embodiment is the creation of incubators by university laboratories ("academic incubators"), which accommodate and support the project carriers before the birth of a company. The science-industry relationship may also take the form of cooperative/joint research which goes far beyond simple transfer. In this case there is actual integration, for example, by the formation of a common institution, a joint research centre. Such a sharing of research between the academic sphere and the private sector involves the joint definition of the output, a long-term strategy, and a mutual learning of working habits.

It seems therefore important that the regional technology policy provides the incentives necessary for the development of a variety of forms of transfer and cooperation between science and industry. This assumes namely the emergence in the academic world of an open attitude towards the local economic environment, favouring the valorisation of the research ouptut, but also the provision of advice or training to companies; an attitude which must not take the place of the central mission of the university : to create knowledge and ensure it is distributed widely through publications and training.

Lastly, whatever the modalities of interaction set up between the University and industry, the local influence of university activity still depends on the environment in which it is located. Surrounded by high tech industries or mature industries, more specialised or more diversified industrial structures, large companies or micro-businesses, the University does not develop the same potentialities. Regional policies have also to take into account these local features.

3. INTERINDUSTRIAL RELATIONSHIPS AND THE "SPECIALISATION VERSUS DIVERSITY" THEMATIC

The Geography of Innovation confirms that Universities are not the only emitters of externalities – instead they are very frequently distributed within industry. So companies are then seen as both sources and receivers of externalities, and the analysis focuses on the level of inter-company spillovers. The main question is then to discover whether local knowledge flows are encouraged more by a specialised environment or a diversified environment. We are referring to the debate revived by E. Glaeser and al. (1992) which opposes the champions of Marshall-Arrow-Romer type externalities, for whom the growth of built-up areas is the result primarily of interactions between specialised agents with similar competencies, and the champions of Jacobs type externalities, for whom conversely the growth of cities is based on the combination of diversified activities.

3.1. The influence of local structures on the production of externalities

Some empirical works study the influence of technology proximity and geographic proximity respectively on the capacity to capture knowledge externalities. Their results seem contradictory. H. Capron and M. Cincera (1995), A. Jaffe, M. Trajtenberg and R. Henderson (1993) show that a significant proportion of the externalities comes from firms which are not in the immediate technological neighbourhood of the firm under consideration.[13] On the other hand, A. Jaffe, M. Trajtenberg and R. Henderson (1992) as well as B. Verspagen and W. Schoenmakers (2000) give greater acknowledgement to the result proving that the probability of citing a patent is positively influenced by the technological proximity between the new patent and the cited patent. C. Autant-Bernard (2002) confirms this positive impact of technological proximity in her analysis of technological interdependencies between French departments.

D. Audretsch and M. Feldman (1999), A. Hageman and M. Kelly (1999) or R. Paci and S. Usai (1999) bring some finer points to the dynamics of local externalities. They leave pure analysis of the role of technological proximity and attempt to isolate within a function of knowledge production the effects of specialisation and diversification respectively on innovation at the local scale. D. Audretsch and M. Feldman (1999) about the United States reveal the driving role of diversity in local innovation. Hence a tight local clustering of industries sharing a common scientific base would tend to stimulate innovation. Specialisation, meanwhile, would have a negative impact. Here we must point out that the idea of employing diversity serves to restrict the effects of externalities generated by

[13] A. Jaffe and al. (1993) working on patent citations in the United States show that approximately 40% of the citations do not come from the same class of patent as the original patent. Similarly, with a technology class

diversity in technologically close sectors. The idea is to focus purely on knowledge externalities by considering that the positive effects of a diversified environment are only identifiable for those sectors linked by the same scientific base (the Silicon Valley or Route 128 cases would not reveal the benefits of specialisation but of diversity).

The work by R. Paci and S. Usai (1999) on local Italian systems requires an identical methodology as D. Audretsch and M. Feldman (1999). Contrary to the assessments carried out by American authors, this time the regressions reveal a positive influence of specialisation and diversity on innovation, with diversity playing an even more consequential role within Metropolitan districts and high tech industries. Such a divergence of results compared to D. Audretsch and M. Feldman (1999), despite a clear-cut methodological proximity in the choice of indicators, suggests a marked difference in the local innovation systems in America and within the European Union.

Applied to the French case, the studies by S. Riou (2001), N. Massard and S. Riou (2002) bring an original point of view. The analysis associates a fairly aggregate nomenclature (11 sectors) and the absence of any hypothesis of technological or scientific proximity to the basis for externalities. Consequently a broad formulation of the diversity indicator is selected. The elasticities resulting from sectoral regressions do not clearly indicate the existence of positive externalities produced by a local structure particular to R&D activities. On the contrary, local specialisation seems to engender an inertia unfavourable to innovation in the departments. The absence of critical mass and/or the effects of competition ensuing from this type of organisation certainly tend to hamper the positive effects from specialisation. An evaluation of the actual diversity impact gives less clear-cut results. To a certain extent, the use of an aggregate nomenclature may be responsible for this. Nevertheless, the need to create external opportunities could explain the positive impact of diversity recorded in sectors with low research activity, whereas further insignificant or even negative results obtained could reveal certain features particular to the French organisation of research which do not favour intersectoral externalities of complementarity.

In a slightly different perspective, studies conducted into the French case by C. Autant-Bernard and N. Massard (1999), C. Autant-Bernard (2000) directly model externalities, as an external R&D stock, and question their intra- or intersectoral origin without restricting the zone of possible interactions between industries.

Then externalities seem at least in part to stem from different sectors of activity (ie the production of innovation in one sector is enhanced by research conducted in sectors of activity other than the one under consideration). More specifically, by comparing local effects with more distant effects, this analysis seems to rely on the idea that sectoral diversity is favourable to the development of externalities within a concentrated geographic zone (D. Audretsch and M. Feldman, 1999) whereas

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nomenclature specifically drawn from European data, Bernstein and Nadiri (1989) estimate citations between classes at over 25%.

sectoral proximity is the basis for the capacity to tap into more distant sources of externalities. But here again, this capacity to take advantage of intra- and intersectoral externalities still seems to vary considerably across each sector.

3.2. Encouraging communication between local industries

3.2.1. Bringing different spheres together

The local economic system is unique, and the existence of geographic externalities bears witness to the idea whereby certain non-transferable interdependencies characterise the Regions. But these are not static or irreversible ; they are subordinate to public action. This is why Regions stand as a key actor in innovation policy. Bearing in mind the principle of subsidiarity, Regional level is adequate to exploit the diversity of local technological connections. The objective here is to valorise comparative regional advantages in technology. For public authorities, this involves here again bringing together different spheres which do not "naturally" rub shoulders: various types of industries, diverse types of companies (in particular according to size).

Measures encouraging direct inter-industrial contacts stimulate an interchange of the tacit knowledge accumulated inside companies. This type of interaction is all the more important as it restricts the phenomena of the obsolescence and depreciation of pertinent technological knowledge to a given moment. This public policy objective is approaching what C. Antonelli (2001) observes within districts, where knowledge assumes the characteristics of a collective activity resulting from the common effort of a variety of connected agents. Even if one admit that it is deceptive to try to artificially reproduce this type of spatial organisation for innovation activity, the reality of technology districts in this case brings lessons which are likely to steer public action. Moreover it will be noted that the act of accentuating the collective character of innovation enables to attenuate the “public/private dilemma” surrounding technology knowledge.

What is at stake here is the promotion of companies from different fields to get together. By particularly encouraging linkages between high tech sectors and traditional industries, the public authorities can improve the diffusion of generic technologies and the hybridisations which are sources of innovation.

It is interesting to point that stimulating the generation of variety is also one of the main roles assigned to technology policy by J.S. Metcalfe (1994) as well as P. Cohendet and P. Llerena (1997). Expanding diversity means increasing the number of possible technical options. In short, the role of diversity within innovation is of particular importance today when innovation occurs mainly through recombinations. Empirical works have shown us how important this diversity may be for the more traditional sectors, which need to find their innovation opportunities externally.

3.2.2. Maintaining multidisciplinary cooperative structures

Experience has shown the difficulties behind implementing local operational institutional networks generating collective innovation processes. On one side appears the problem of how to articulate these institutional networks, created and maintained by regional institutions, with ad hoc local industrial system. On the other side, setting up transverse cooperations between the local players becomes difficult when the latter do not enjoy organisational proximity.

However, intercompany contacts may be stimulated by regional programmes which support cooperation projects. In this context, it seems important to encourage trans-sectoral cooperative structures and on a wider level, meetings on a transverse theme. Numerous theoretical and empirical works highlight the importance of supply-demand relationships in the dynamic of intersectoral cooperations bringing new opportunities. So there could be a very clear advantage in moving on from policies purely angled towards research and innovation supply, in order to look towards the promotion of local demand.

4. LOCAL/GLOBAL CONNECTION AND ABSORPTIVE CAPACITY

The Geography of Innovation also shows that knowledge externalities are not purely local, one-dimensional phenomena. They are simultaneously local and global and emanate from a variety of sources. In fact, while being supported by various geographical levels in the United States in particular (counties, metropolitan districts or states), every time the existence of externalities internal to the zone is revealed. When studies compare different geographical scales (C. Autant-Bernard for France or L. Bottazzi and G. Pieri, 2001, for Italy), different levels of diffusion appear, even if the local effects take precedence in certain circumstances. Our analysis would benefit from stipulating the reasons behind such combinations. To do this it is necessary to acquire a better understanding of the ways and conditions in which technological externalities are transmitted, starting with the concept of "absorptive capacity" (W. Cohen and D. Levinthal, 1989).

4.1. Shortcomings in the absorptive capacity of remote external resources

4.1.1. Asymmetry in regard to the level of internal research

An initial condition for the capture of knowledge externalities would be the constitution of an absorptive capacity. According to G. Dosi (1988), W. Cohen and D. Levinthal (1989), in order to capture technological externalities it is necessary to have adequate internal skills and competencies (important level of internal research, diversity of available competencies). Firms strive to build their own absorptive capacity – in other words: to have a certain amount of knowledge in order to be able to identify and exploit new available knowledge in their environment.

Widely accepted from a theoretical point of view, this idea has given rise to few empirical works. In particular, the definition of the absorptive capacity at the aggregate level of geographic zones and its influence on the geographic dimension of externalities is poorly documented.

C. Autant-Bernard (2000) argues that the research level and its degree of diversity may not simply affect the level of externalities captured within a local context, but also their geographic origin. In any case, this is what emerges from her analysis of the French case. Having a high and varied level of internal competencies seems vital in the capacity to take advantage of remote knowledge sources. Conversely, zones which are not very active on the research side or are very specialised seem more able to take advantage of neighbouring sources of externalities. Therefore the absorptive capacity would play more on the capacity to tap into remote sources of externalities than on the level of externalities captured.

4.1.2. The risk of regional lock-in

The problem of asymmetry between companies or geographic zones, in their capacity to absorb external resources is magnified if we take into account a main result of the Economics of Innovation : one of the key features of technology is its localised character, in all senses of the term, including the geographical one (for example C. Antonelli, 1999 ; J.S. Metcalfe, 1994). This specificity stems from path dependency. In addition, concerning the risk of regional lock-in it will be noted that local institutions may stimulate innovation sometimes, and hinder it at others. This risk seems even greater if we consider that the institutional change is characterised by a phenomenon of inertia which makes it generally incremental and slow.

As a result, the regional dynamic may be positive, but it also encompasses a risk of lock-in. A business may find itself trapped with an old technique because the local system is not supplying the right technology. A tight local network may exclude the vital information (B. Carlsson and S. Jacobsson, 1997 ; E. Ernberg and S. Jacobsson, 1997).

The risk of regional lock-in justifies a public intervention so that the regional dynamic is a strength for the local firms instead of a weakness. Here the objective is to provide the conditions necessary for the regional innovation system to evolve, which requires a systematic promotion of opening up towards the outside and diversity in the broadest sense. This point is crucial in a time of change which triggers a heightened level of uncertainty (B. Johnson, 1992).

4.1.3. Barriers to entering networks

As B.A Lundvall (1998) shows, the situation today may also be interpreted as the transition to an "economy of networks" through which pertinent knowledge flows: increasingly, strategic skills are developed in an interactive way, and shared within networks. But access to these networks is not open and free. Among other things, it presupposes the sharing of tacit knowledge, or codified knowledge with codes which are difficult to track down (R. Cowan, D. Foray, 1997 ; P. Maskell, 2001). Yet the capacity to join these tight networks determines the access to knowledge – today's most strategic resource – and hence the status of individuals and companies within economic space. The existence of barriers blocking the entrance to these networks, in which knowledge is produced and transmitted, pinpoints a field of intervention for the regional technology policy.

4.2. Connecting the local innovation system to national and international levels

4.2.1. Promoting learning

The concept of "a learning economy" (B.A. Lundvall, 1998) synthesises the idea whereby if knowledge is nowadays the most strategic resource, learning constitutes the most important process in economics. As a matter of fact, access to scientific and technological knowledge does not simply presuppose the system has a good "distribution power" (P. David and D. Foray, 1994) – to ensure availability of this input – but also the capacity of companies to absorb external resources, a particularly challenging exercise bearing in mind the current speed of development. From this point of view, it is clear that there is a minimum activity threshold in research or technology activity below which "nothing happens", which means that no learning dynamic is likely to develop. This firstly poses the question of small structures (companies or regions), and the importance of the basic means to set in place.

If - as seen earlier - the available diversity of skills is favourable for local learning, the development of poles of specialisation must not be overlooked, because without them the capture of leading edge knowledge from distant centres of excellence seems to be impossible.

It is then down to the public authorities to develop the means of learning and the capacity to communicate – because learning is deeply affected by the institutional architecture (B. Carlsson, S. Jacobson, 1997). Such a target presupposes a long term interventionism, as learning is far more than a transfer of information and cannot be reduced to a single transaction (M. Fadairo and N. Massard, 2000).

For this reason, we argue that an education policy is an integral part of the innovation policy, which goes beyond the quantitative issue of funding. The education system is involved in every level: "*from nurseries to the training of engineers and scientists*" (B. A. Lundvall 1992, page 302).

In a more concrete way, developing an education system requires improving the physical infrastructures, equipment and human resources. Here the key role of the University again becomes apparent (P. Caracostas, L. Soete, 1997; B.A. Lundvall, 1992). Training also helps maintain the "creative forgetting" necessary to move from one technology to another. A further education policy, for example, follows this principle.

Apart from developing the means to learn, public intervention may also help stimulate learning. For example this could be done financially on the individual level by distributing rewards according to the learning and creative effort (B.A. Lundvall, 1992), and within a company by a tax incentive policy. It seems important to stress incentives focusing on the personal contribution to the group performance rather than simply on individual effort ; this choice encourages the incentive to cooperate.

4.2.2. Developing communication infrastructures

As seen before by including public actions in education and training as an integral part of the innovation policy, the results of the Geography of Innovation plead in favour of a technology policy in the broadest sense. This long term interventionism corresponds to setting conditions favourable for innovation, rather than direct, targeted intervention. This characteristic recurs in another measure necessary for the capture of external knowledge : the development of communication infrastructures, in all their forms.

It is worth making several comments on this point. First of all, we are reminded that in the ideal situation defined by P. Dasgupta and P. David (1994), access to new knowledge is broad, fast and free. These features determine a "system's distribution power" and naturally depend on the quality of the communication infrastructures. From this point of view, all actions encouraging the codification of new knowledge constitute the first stage in communications policy.

In addition it appears necessary to stress the role of diversity in the means of communication, diversity whose actual promotion constitutes an important objective in its own within technology policy (P. Cohendet, P. Llerena, 1997).

Our last remark concerns the decisive place of the new information and communication technologies within access to external knowledge. Promoting their development and their diffusion at the local level diverts potential partitioning. Even though the geographic dimension still has a meaning – as shown by econometric works – these technologies considerably weaken the constraints of physical distance. For this reason, the role of spatial dispersion takes today a back seat behind the role of professional communities, which share a code, a language and more generally a culture.

4.2.3. Promoting the access of local companies to the European programmes

In the European Union, the existence of a Community technology policy is an undeniable asset for the Regions. The formation of international cooperative structures, driven by the European programmes, gives local businesses the possibility of correcting any weak points in their absorptive capacity. It is a means of escaping from the dependency on the local path, to access closed networks and tap into international technological externalities.

This global participation constitutes a major element in local dynamism as small innovative businesses largely rely on external sources of knowledge (D. Audretsch, 1995) and their active strategies in this field, their capacity to develop informal sources of knowledge diffusion (based on face-to-face contacts and the mobility of researchers) places them, according to D. Audretsch (1995, 2001), in a position of essential players in the production and valorisation of local technological externalities.

At the moment, one problem is that despite the efforts[14], the proportion of SMEs taking part into the Community programmes remains low (M. Fadairo, 2001). Now these companies are characterised by their limited means for internal research, and hence by their inadequate absorptive capacity.

Here is a very large field of action for regional innovation policy: to clear away any institutional barriers, to promote the participation of SMEs and more generally of regional firms, in the European programmes. This is a question of teasing out any overlap between the local, national and European systems : the diversity of institutions increases the possibilities for communication and interaction, and hence for innovation.

The role of training and codification, put forward in this article, merits again to be emphasised: these elements represent the conditions necessary to access common and evolutionary languages. Moreover, encouraging advisory activities for SMEs at a regional level in order to allow them to join the Community cooperative structures is justified here.

[14] of the European Commission, notably.

5. CONCLUSIONS

In his 1994 article, J.S. Metcalfe identifies two main profiles in technology policies: i) those which take the possibilities of innovation as given, and thus seek to stimulate innovation by reducing the cost of R&D activity or by increasing the profitability of private innovation; ii) those which seek to expand these opportunities. The advantage of the second perspective, favoured by the author, is confirmed by the results of the Geography of Innovation. In this sense, technology policy is far more than a justification for R&D expenditure or for the direct production of artefacts. Its role is also to put in place and justify the variety of mechanisms which facilitate the capture and assimilation of local, national and international external knowledge.

The geographic dimension of knowledge externalities, as confirmed by the econometric works, gives an important place to the regional intervention level, because it is at this level that the geographic externalities can be exploited, whether they are flowing from science to industry or remaining intra-industrial. However, regional technology policy has another equally important side: promoting an opening up to the rest of the world. This involves connecting the regional innovation system to the national and supranational system, hence an explicit choice for articulating the different territorial levels of public intervention: regional, national, EU-based, within the European Union.

The main result of the Geography of Innovation is to make obvious that the diffusion of technology knowledge is complex, hence the need for a varied institutional – and territorial - infrastructure where overall coherence is provided by public choices.

Within the European Union the "Community" policy of innovation involves a sharing of skills. Our analysis shows that outside the problems that this situation inherently poses, this territorial organisation by multiple governance should be considered as an asset.

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